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VISÉAN

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(8 figures)

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ABSTRACT. The quality exposure of Viséan rocks in southern Belgium, the diversity of facies, the pioneer palaeontological works that started in the mid 19th century and the development of the foraminifer, conodont and rugose corals zonations in the last decades were the main elements for the promotion of the international use of the Viséan Stage. Southern Belgium is probably the best-documented area for the Viséan Stage in the world. In the Namur-Dinant Basin the submarine topographic irregularities inherited from the late Tournaisian and due to different sedimentation rates on the platform, in the basin and on the Waulsortian buildups were progressively smoothed out by the Viséan sedimentation. During the Tournaisian/Viséan transition, the central Dinant type area was in a peculiar, restricted environment and poorly fossiliferous, peri-Waulsortian facies developed. A new criterion for a better definition of the base of the stage was needed and has now been adopted. It is based on the evolutionary lineage of the foraminifer Eoparastaffella. A proposed new GSSP (Global Stratotype Section and Point) in Southern China (the Pengchong section) is still under discussion, but the term Viséan will remain as a stage corresponding to the Middle Series of the Mississippian Subsystem.

KEYWORDS: Viséan, Belgium, Lithostratigraphy, Biostratigraphy, Palaeogeography.

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1. Name

Viséan (English), Viseaan (Dutch), Viseum (German), Viséen (French).

2. Age

The Viséan is included in the late Mississippian Epoch (359.2 - 318.1 Ma) of the Carboniferous Period. It has a duration of about 19 Ma, ranging from 345.3 ± 2.1 to 326.4 ± 1.6 Ma (Geological Time Scale 'GTS 2004' in Gradstein *et al.*, 2004). These figures are indicative as available radiometric dates are scarce, not from the type-area and poorly constrained stratigraphically.

3. Authors

The subdivision of the Lower Carboniferous into 2 stages that were later to be named "calcaire de Tournai" (or Tournaisian) and "calcaire de Visé" (or Viséan) was already made by Dumont (1832). The first mention of the "calcaire carbonifère de Visé" is given by de Koninck (1842-1844). It was to become the "étage du calcaire de Visé" in Gosselet (1860) and "étage de Visé" in the legend of 6 sheets of the geological map of Belgium at scale 20.000 (Dupont, 1882-1883).

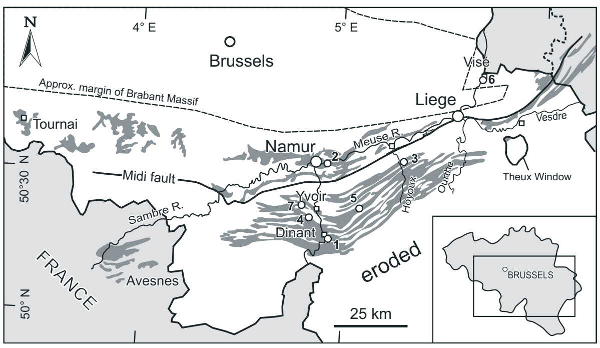

Figure 1. Location of the sections mentioned in the text. The shaded area represents Lower Carboniferous outcrops. 1. Bastion; 2. Lives; 3. Royseux; 4. Salet; 5. Sovet; 6. Visé; 7. Warnant.

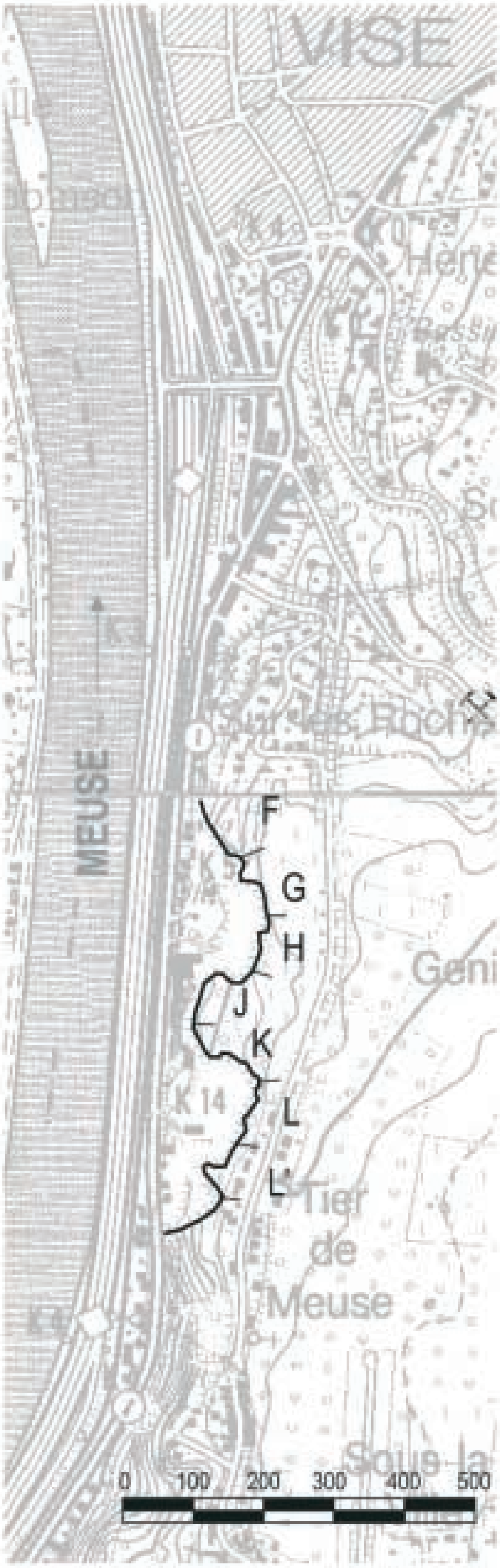

Figure 2. Location of the Viséan historical type area, in quarries "F" to "L" between Argenteau and Visé (from Poty, 1982).

4. Historical type area

Geological map Dalhem – Herve (42/3-4; Barchy & Marion, 2000).

The "calcaire de Visé" refers to the small town of Visé in eastern Belgium, at the border with the Netherlands (Fig. 1). Quarries "F" to "L" were opened in the Viséan limestone, along the right bank of the Meuse River, between the Hermalle bridge and the town of Visé (Figs 2-3; Demanet, 1958; Pirlet, 1967, Poty, 1982). This historical type area was however not retained for the formal definition of the base of the Viséan, fixed in the Dinant area, at the 6th International Carboniferous Congress (Sheffield, 1967), more than one century after the pioneer works of Dumont (Fig. 4; see 6.).

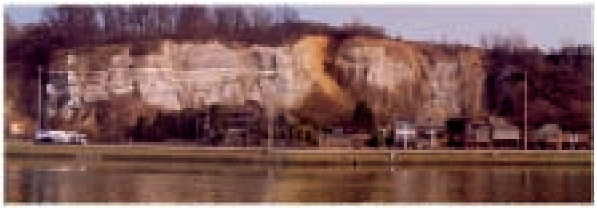

Figure 3. View of the old quarries "F"-"G" on the right bank of the Meuse valley, south of Visé, historical type locality of the Viséan. A: Visé Limestone Fm, upper part of the Lower Warnantian (MFZ14-RC7β). It is from this limestone that most "Visé fossils" were extracted during the XIXth century; B: Palaeokarstic surface; C: Upper Warnantian dolomitized limestones; D: Souvré Fm, Namurian (E2 Zone), silicified shales and limestones (lydites).

Figure 4. The Viséan boundary stratotype at Dinant in the Bastion section.

5. Description

The stage is only partially exposed in its historical type area and its base cannot be located there. It corresponds to the pale to grey limestones of the Visé Formation (Fig. 5; Poty *et al.*, 2002; Barchy & Marion, 2000) which are characterized by four main facies:

- sedimentary limestone breccias with centimetric to pluri-decametric boulders of Frasnian age ("cyclopean breccia") ;
- thick-bedded packstones to rudstones, with sedimentary breccias, forming fining-upward pluri-decimetric to metric parasequences, often laminated in their upper part;
- thick-bedded to massive packstones to rudstones ;
- massive algal and bioclastic boundstones forming buildups with abundant brachiopods.

The thickness of the Visé Fm in the Visé Sedimentation Area (VSA, Hance *et al.*, 2001) varies from zero to several hundreds of metres, because of the major syn-sedimentary tectonics of the area (Poty, 1982, 1991, 1997). It is more than 100 m in the Visé quarries. The age ranges from late Tournaisian to late Viséan, with numerous stratigraphic gaps. The Livian substage is always absent.

6. Historical background

In 1856, Dumont specified the subdivisions introduced in 1832 (see 3.) and used "calcaire à crinoïdes" and "calcaire à Productus" for his lower and upper stages. The correspondence respectively with the "calcaire de Tournai" and with the "calcaire the Visé" is obvious. Gosselet (1860) confirmed the stratigraphical succession "calcaire de Tournai"/"calcaire de Visé" and more formally subdivided the "Terrain Carbonifère" into 3 stages. The "Etage du calcaire de Visé" was the middle stage, included between the older "Etage du calcaire de Tournai" and the younger "Etage houiller". De Koninck only approved this succession in 1878. Although he was obviously not a stratigrapher, he promoted the international recognition of these 2 stages, by the quality of his palaeontological studies on the Tournai and Visé fauna.

Dupont (1861, 1863) first identified the same succession in the Dinant area where it is more complete, but lateral facies changes were not well understood and were explained by gaps in the succession. In 1865, he introduced the stratigraphic term "Assise de Dinant", corresponding to the base of the Viséan. In the legend of the 1/20000 geological map of Belgium, Dupont (1882-1883) used the term "Etage de Visé à *Chonetes comoïdes* et *Productus undatus*" for the upper stage of the "calcaire carbonifère", succeeding the "Etage Waulsortien". More than a century after the pioneer works of Dumont, at the 6th International Carboniferous Congress (Sheffield, 1967), a Tournaisian-Viséan boundary stratotype was formally adopted in the Dinant Basin, following the proposal of Conil (SCCS, 1969). The base of the Viséan now corresponded to the base of bed 141, the first black limestone intercalation (*"Calcaires et Marbres Noirs")* in the Leffe facies at the Bastion section in the historical type area (Fig. 4). This level coincides with the first occurrence of the calcareous foraminifer genus *Eoparastaffella* (Conil *et al.*, 1969), less than 1 m below the entry of the conodont *Gnathodus homopunctatus* (Groessens & Noël, 1977). In 1977, Conil *et al* erected the Tournaisian and Viséan as series, subdivided into stages. An auxiliary Viséan boundary stratotype was defined at the route de Salet in the Molignée Valley by the same authors. The Salet section is the stratotype for the base of the Moliniacian Stage, the proposed as the first stage of the Viséan in Belgium. This coincidence between the base of the Viséan and that of the Moliniacian was revealed to be incorrect after the discovery of « Viséan-like » faunas below the base of the Viséan in the Bastion section, indicating that the first Viséan Stage (Moliniacian – now a substage) correlates in part with the latest Tournaisian (Conil *et al.*, 1989).

Altough formally defined, the base of the Viséan was unsatisfactory, not only for long distance correlations, but also at the local scale. The problem is related to the peculiar palaeogeographical context of the Dinant region at the time of the Tournaisian-Viséan transition (see 13.). A Working Group on the Tournaisian-Viséan boundary was therefore set up by the Subcommission on Carboniferous Stratigraphy (SCCS) to re-examine potential levels for defining the base of the Viséan and to search for a suitable GSSP (see discussion in Devuyst *et al.* 2003).

As a result Hance & Muchez (1995) proposed that the boundary should be placed at the appearance of the first foraminifer *Eoparastaffella* with an outer subangular periphery (morphotype 2) succeeding forms characterized by a rounded periphery (morphotype 1; Fig. 8). This proposed criterion did not change significantly the chronostratigraphic position of the boundary from its 1969 definition but necessitated finding a new stratotype because morphotype 1 does not occur in the existing Bastion stratotype in the Dinant Basin. This proposal was subsequently refined (Hance, 1997; Sevastopulo *et al.*, 2002) and approved by a ballot of the Voting Members of the SCCS (Work, 2002). The search for a GSSP candidate failed in Belgium, but a section yielding a complete evolutionary lineage of *Eoparastaffella* was found at Pengchong (South China) and was proposed as a new GSSP by Devuyst *et al.* (2003). The approval of this GSSP is still in process but has still to be ratified. The best Belgian locality for the base of the Viséan is the Sovet railway, parastratotype for the base of the Moliniacian (Poty *et al.*, in press). In the last ratified global Carboniferous subdivision scheme, the Viséan Stage is the only stage of the Middle Mississippian Series (Heckel, 2004).

7. Lithology

The Lower Viséan lithostratigraphical pattern appears rather complicated with gaps in the Namur, Condroz and Avesnes South Sedimentation Areas (S.A.) and a more continuous succession in the Dinant S.A. and at the southern margin of the Condroz S.A. (Figs 5-6). In the latter areas, influxes of sediments derived from shallower areas occur in the dominantly micritic Leffe Fm. They form thin grainstone layers and locally conglomerates. Higher in the succession, packstones with abundant moravamminids constitute the dominant facies. The peritidal sediments of the Terwagne Fm are the first Viséan sediments recorded on the shelf. Bioclastic moravamminids packstones and grainstones are dominant in the Sovet Fm whereas mudstones, wackestones and peloidal and bioclastic grainstones characterize the Molignée Fm. Grainstones and bioclastic packstones are dominant in the Salet Fm. The prograding Neffe Fm (mainly bioclastic grainstones) filled in the irregularities of the early Viséan sea-floor topography. The Lives Fm that was deposited throughout the Franco-Belgian Basin consists of peritidal facies, subtidal bioclastic packstones, locally cherty, and stromatolites organised in parasequences. The Seilles Mbr of the Grand-Malade Fm is similarly characterized by parasequences in which bioclastic grainstones and packstones are dominant. The Maizeret Mbr is a peritidal lateral equivalent of the Seilles Mbr, with pseudomorphs after evaporites, dolomites and breccias. The Bay-Bonnet Mbr is the youngest unit of the Grand-Malade Fm and consists dominantly of stromatolitic limestone. The Bonne River Fm, which follows, includes the crinoidal pack- to grainstones of the Thon-Samson Mbr and the dark, sometimes cherty, mudstones and stromatolitic limestones of the Poilvache Mbr. The Anhée Fm is the last Viséan formation with dark wackestones and packstones in its lower member and argillaceous limestones, shales and siliceous shales whith phosphatic nodules in its upper member.

In the Hainaut Sedimentation Area, the base of the Viséan has to be searched for above the Lens Limestone. In the Saint-Ghislain drillhole, the Viséan succession is about 1150 m-thick and includes three major evaporitic units (Groessens *et al.*, 1982).

8. Sedimentology and palaeogeography

During the late Tournaisian and early Viséan, the ramp setting that prevailed during the early Tournaisian progressively evolved to a rimmed-shelf and to a broad flat-topped platform of regional extend during the middle and late Viséan (Livian – Warnantian, Hance *et al.*, 2001; see Fig. 5 of Hance *et al.*, The Tournaisian Stage, this volume). The shoreline was situated along the southern border of the Brabant Massif. In the latest Tournaisian, the shelf edge was located in the Yvoir – Sovet area. A restricted succession was deposited in the Dinant S.A., between the prograding platform to the north and the discontinuous Waulsortian complex to the south (Fig. 6; Lees, 1997). The facies reflect this peculiar setting and have poor benthic assemblages, hampering correlation with shallower but more open marine areas. Submarine topographic irregularities inherited from different sedimentation rates on the platform and in the Waulsortian buildups were smoothed out in the late Moliniacian and early Livian. During the Livian (Middle Viséan) and Warnantian (Upper Viséan), sedimentation was governed by an aggrading shelf extending from western Germany to southern Ireland with laterally wide ranging parasequences. Open marine facies were restricted to the north, while evaporites developed in the south. Warnantian deposits are locally missing. In the Dinant sedimentation area, this gap only includes the uppermost Warnantian and basal Namurian (E1 goniatite Zone), whereas in the northern part of the Namur sedimentation area it extends stratigraphically downwards to the uppermost Livian (Hance *et al.*, 2001)

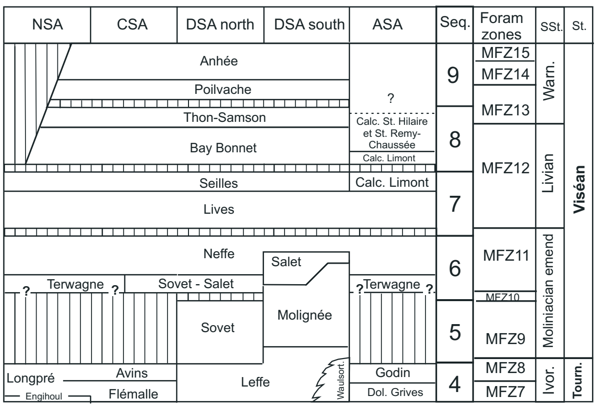

Figure 5. Lithostratigraphic framework for the Viséan of Belgium and Northern France (modified from Poty *et al.*, in press).

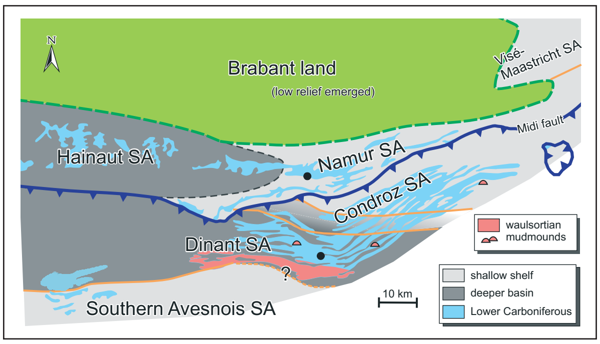

Figure 6. Paleogeography of the Namur-Dinant Basin at the time of the Tournaisian-Viséan transition (modified from Poty *et al.*, 2001).

Five third-order sequences are identified in the Viséan of southern Belgium (Hance *et al.*, 2001, 2002; Poty *et al*, 2001). A similar situation is observed in northern France (Hance *et al.*, 2001), south-western Britain (Hance *et al.*, 2002) and Poland (Poty *et al.*, in press).

9. Palaeontology

9.1. Foraminifers

This group is more diversified and abundant than in the Tournaisian. It reflects the development of shallow shelf areas, more suitable for foraminifers. Seven interval zones, MFZ9 to MFZ15 have been redefined recently by Devuyst & Hance (in Poty *et al.*, in press), with emphasis on taxa useful for long distance correlation (Fig. 7). Representatives of the Archaediscidae, Endothyridae, Ozawainellidae and Palaeotextulariidae yield most of the stratigraphically important taxa.

9.2. Rugose corals

Rugose corals are particularly abundant in the open marine shallow water facies which are widespread in the Viséan. The biozonation of Poty (1985; 1991 in Conil *et al.*) has been revised in Poty *et al.* (in press) and correlated with the foraminifer and conodont zonal schemes (Fig. 7). The base of the RC4β2 Subzone matches approximately the base of the MFZ9 Foraminifer zone, which coincides with the base of the Viséan. Zones RC5 to RC8 cover the late early- to late Viséan.

9.3. Conodonts

Viséan conodonts are much less abundant and diversified than their Tournaisian counterparts. The key references are: Groessens (1975); Belka & Groessens (1986); Conil *et al.* (1991); and Webster & Groessens (1991). *Gnathodus homopunctatus* is a useful guide for the base of the Viséan; it enters in the Bastion section less than 1 m above the base of the Viséan (Conil *et al.* 1991).

9.4. Other groups

Abundant illustration of the Viséan macrofauna (brachiopods, gastropods, bivalves, crinoids, cephalopods) can be found in the pioneer works of de Koninck (1842-1844), based mainly on the fauna from the Visé area. Subsequent papers are numerous and the reader should refer to Demanet (1958). A special mention has to be made of the exceptionally well preserved fauna of the "Marbre noir de Dinant/Denée" (Molignée Fm; e.g. Delépine, 1928; Fournier & Kaisin, 1928; Fournier & Pruvost, 1928; Demanet, 1929; Mottequin, 2004).

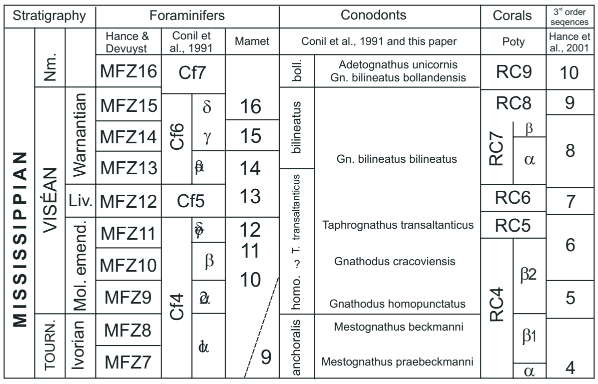

Figure 7. Biostratigraphic framework for the Viséan of Belgium (modified from Poty *et al.*, in press).

10. Chronostratigraphy

The new criterion for the base of the Viséan proposed by Devuyst *et al.* (2003), which has been formally approved by the Voting Members of the SCCS in 2002 (Work, 2002), is the first appearance of *Eoparastaffella simplex* in the lineage *E.* '*ovalis*' → *E. simplex* (Fig. 8). It offers the advantage of keeping the base of the Viséan very close to its historical definition (Conil *et al.*, 1969). The *Eoparastaffella* lineage is particularly well documented in the Pengchong section (Southern China), proposed as a new GSSP by Devuyst *et al.* (2003). A biometric study of this lineage combined with the use of previously neglected taxa (Hance & Devuyst in Poty *et al.*, in press) offers a biostratigraphic resolution that was never attained at this level before (Devuyst *et al.*, 2005). The conodont *Gnathodus homopunctatus* enters a decimetre above the boundary in Pengchong. Correlation with the Dinant historical type-area is very good.

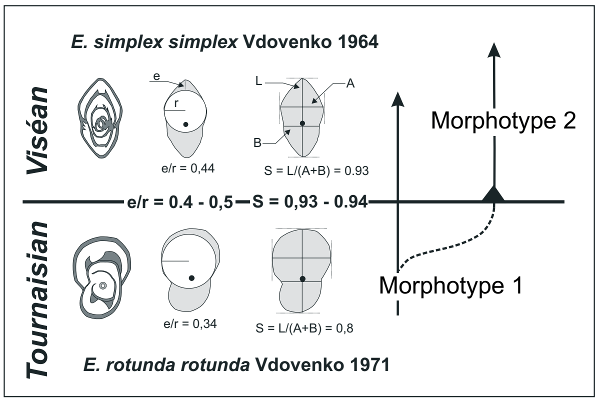

Figure 8. *Eoparastaffella* morphotypes and their use in defining the base of the Viséan (from Devuyst *et al.*, 2003).

11. Geochronology

At present, the only available reliable date close to the base of the Viséan is from an ignimbrite in Eastern Australia (see Roberts *et al.*, 1995), however precise correlation with Western Europe and Southern China is problematical. No radiometric data are available yet from the Belgian Viséan. A few bentonite horizons containing zircons (Delcambre, 1989) are currently being processed to try to obtain stratigraphically well-constrained dates in the Lower Viséan.

12. Structural setting

The Dinant S.A. and the Condroz S.A. are included in the Dinant "Synclinorium" which was part of the Ardennes Allochthon. The Lower Carboniferous formations and the Famennian siliciclastics form respectively the core of synclines and anticlines. Palaeogeographic reconstructions require restoration of the Ardennes Allochthon to its original position, 25 to 30 km southwards.
The Hainaut S.A. and the northern part of the Namur S.A. correspond to the Brabant Parautochthon (northern flank of the Namur "Synclinorium"). The southern part of the Namur S.A. is exposed in the thrust sheets distributed along the Midi fault (southern flank of the Namur "Synclinorium"). The earliest phase of the Variscan orogeny is recorded in the Middle Viséan, with the development of proximal facies southward, as a result of the uplift of the Ardennes (Hance *et al.*, 2001).
The Visé S.A. has a complex tectonic history and sedimentation is governed by block faulting (Poty, 1997).

13. Reference sections in Belgium

Visé Sedimentation Area
- Quarries F to L between Argenteau and Visé (Fig. 2; Demanet, 1958; Pirlet, 1967; Poty, 1982).

Dinant Sedimentation Area
- Bastion section and Lambert quarry (Fig. 3; Conil *et al.*, 1969; Groessens & Noël, 1977; Hance, 1988; Conil *et al.*, 1988, 1989).
- Salet road section (Belka & Groessens, 1986; Hance, 1988; Hance *et al.*, 1994; Conil *et al.*, 1989; Devuyst *et al.*, this volume; Poty *et al.*, in press).
- Sovet railroad section (Segura, 1973; Hance, 1988; Conil *et al.*, 1988; Devuyst *et al.*, this volume; Poty *et al.*, in press).
- Warnant, Dejaiffe quarry (Laloux *et al.*, 1988 ; Poty & Hance, The Warnantian Substage, this volume)
- Royseux (Aretz, 2001; Poty & Hance, The Warnantian Substage, this volume).

Namur Sedimentation Area
- Lives cliffs (Poty & Hance, The Livian Substage, this volume)

14. Main contributions

de Dorlodot, 1895; Delépine 1911; Demanet, 1958 ; Conil *et al.*, 1977 ; Groessens *et al.*, 1982; Paproth *et al.*, 1983 ; Conil *et al.*, 1991 ; Hance *et al* (in press).

15. Remarks

The Viséan is currently the only stage of the Middle Series of the Mississippian Subsystem (Heckel, 2004); its elevation to the rank of series is possible but requires also the elevation of selected local substages to the stage level. This would require for each the definition of a a biostratigraphic criterion useful for long distance correlation and an appropriate GSSP.

16. Acknowledgements

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